

## ON-FREQUENCY REPEATER

**[0001]** This application is based on, and claims priority of, United States Patent Application No. 09/809,218, filed on March 16, 2001.

[0002] Not Applicable.

**[0003]** The present application relates to wireless access networks and, in particular, to a method and system for enabling Intelligent Gain Control (IGC) in an on-frequency repeater.

[0004] In the modern communications space, wireless access networks are increasingly popular, as they enable subscribers to access communications services without being tied to a fixed, wireline communications device. Conventional wireless access network infrastructure (e.g., base stations) is typically "built out", by a network service provider, using a network-centric approach. Thus the build-out normally begins with major Metropolitan Service Areas (MSAs) using base stations located at the center of overlapping coverage areas or "cells". The build-out, and corresponding wireless communications services, subsequently migrates outward from the MSAs to areas of lower population/service densities (e.g., urban to suburban to rural, etc.). At some point, usually dictated

by economics, the build-out slows and/or becomes spotty leaving many individual wireless subscribers with unreliable or non-existent service.

[0005] On-frequency repeaters are known in the art for improving wireless services within defined regions of a wireless network (e.g., within a building or a built-up area). Such on-frequency repeaters are typically provided by the wireless network provider in order to improve signal quality in high noise or attenuation environments, where signal levels would otherwise be too low for satisfactory quality of service. In some cases, a wireless network provider may install a repeater in order to improve service in an area lying at an edge of the coverage area serviced by a base station, thereby effectively extending the reach of the base-station.

[0006] Prior art repeaters are part of a network-centric view of the wireless network space, in that they are comparatively large systems provided by the network provider in order to improve wireless service to multiple subscribers within a defined area. As such, they form part of the network "build-out plan" of the network provider. These systems suffer the disadvantage in that an individual subscriber cannot benefit from the improved services afforded by the repeater unless they happen to be located within the coverage area of the repeater. However, there are many instances in which wireless subscribers may reside or work in areas where the coverage area of the wireless network is unreliable. Typical examples include mobile subscribers, and subscribers located in suburban and rural areas. Also, in-building coverage can be unreliable even within MSAs, depending on the size, location and construction of buildings and/or other obstacles. In such

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**[0008]** As described in United States Patent Application No. 09/809,218, the APR represents a subscriber-centric solution for improving wireless services as required by one or more subscribers, and in a manner that is transparent to the network. However, in order to provide this functionality, it is necessary for the repeater to provide

sufficient system gain in each of the uplink and downlink paths to compensate for propagation losses in these paths. On the other hand, if the gain (in either the uplink or downlink paths) is too high, the repeater will radiate unnecessarily high signal powers to the subscriber's WCD and/or the base station. In an environment in which there is more than one APR in use, radiation of excessive signal power in the downlink path can cause interference (in the form of multiple overlapping coverage areas) with other subscribers. The same holds true for a single APR radiating excessive power in the downlink path causing interference to other subscribers outside the personal wireless space. Similarly, radiation of excessive signal power to the base-station may cause interference with other base-stations and/or other users of the wireless communications network.

[0009] Automatic Gain Controllers (AGCs) capable of controlling signal gain are known in the art. Typically, AGCs are implemented as analog RF or IF circuits, in which a (voltage controlled) variable gain amplifier (VGA) is used to amplify the analog signal. The VGA is normally controlled by a voltage level of a control signal, which is usually generated (by a comparator) by comparing a measured parameter (e.g., a received signal power, or a bit error rate) to a predetermined threshold value. AGCs of this type are capable of providing reliable operation within the range of linear operation of the VGA. Typically, operation of the AGC becomes increasingly unreliable beyond the linear range of the VGA, and thus the performance of the AGC is typically limited by the linear range of the VGA. However, it is anticipated that successful operation of the repeater will require that system gain be controllable through a range of up to about 120dB in both the uplink and

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[0011] Accordingly, a method and apparatus capable of automatically controlling gain throughout a wide operating range, in order to compensate for propagation losses and imperfect antenna isolation, at a moderate cost, remains highly desirable.

**[0012]** An object of the present invention is to provide an apparatus for automatically controlling gain throughout a wide operating range.

**[0013]** Accordingly, an aspect of the present invention provides an intelligent gain controller (IGC) adapted to control a gain of first and second wideband signal paths. The IGC comprises a respective automatic gain control (AGC)

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**[0016]** The AGC feed-back loop may include means for controlling a power level of the feedback signal supplied to the AGC VGA, using an AGC control set signal from the micro controller. The means for controlling the power

**[0020]** In some embodiments, the means for channeling RF signals includes: a switching input and a filter. The switching unit operates to select RF signals from one of the first and second wideband signal paths, while the filter attenuates a portion of the selected RF signals

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**[0024]** The software code for monitoring the power level of RF signals may also include software code designed to decorrelate desired RF signals from undesired leakage signals within each of the wideband signal paths. This software code may be designed to: inject a predetermined unique code into a selected one of the wideband signal paths; detect a power level of the predetermined unique code in the monitored RF signal; and determine a proportion of leakage signals in the monitored RF signal using on the detected power level of the predetermined unique code in



the monitored RF signal. The proportion of leakage signals in the monitored RF signals may then be used to adjust the optimum gain in each one of the respective automatic gain control (AGC) blocks.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0025] Further features and advantages of the present invention will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

[0026] Fig. 1 is a block diagram schematically illustrating principle elements of an exemplary Adaptive Personal Repeater in which the present invention may be deployed;

[0027] FIG. 2 is a block diagram schematically illustrating principle elements of an exemplary Intelligent Gain Controller (IGC) in accordance with an embodiment of the present invention;

[0028] FIG. 3 is a block diagram schematically illustrating principle elements of an exemplary uplink AGC usable in the IGC of FIG. 2;

[0029] FIG. 4 is a block diagram schematically illustrating principle elements of an exemplary downlink AGC usable in the IGC of FIG. 2; and

[0030] FIG. 5 is a block diagram schematically illustrating principal elements of exemplary down converter and micro controller modules usable in the IGC of FIG. 2.

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[0032] The following description utilizes exemplary power levels, power ranges, channel frequencies and band-widths in order to illustrate various features of the present invention. Those skilled in the art will appreciate, however, that the present invention is by no means limited to such values. On the contrary, those skilled in the art will readily understand that the present invention can be deployed for use in conjunction with any wireless communications network, and it is to be expected that the power levels, power ranges, channel frequencies, and band-widths stated herein will be modified to conform to the requirements of the communications network in question. Such modifications are considered to be well within the purview of those of ordinary skill in the art, and lie within the intended scope of the appended claims.

**[0033]** The present invention provides an Intelligent Gain Controller (IGC) for use in an on-frequency repeater, such as, for example, an Adaptive Personal Repeater (APR) described in applicant's co-pending U.S. Patent Application No. 09/809,218. In general, an on-frequency repeater operates to mediate RF signal traffic between transceivers of the wireless communications network. Thus the APR creates a local wireless space encompassing one or more mobile transceivers (e.g., subscribers' wireless communications device(s)), and maintains a reliable fixed wireless link to a fixed transceiver (e.g., a base station) in order to "reach back" into the reliable coverage area of

the wireless communications network to provide high quality wireless services in an otherwise poorly serviced area of the network. The IGC operates to control the gain of the repeater to facilitate reliable communications between the subscriber's wireless communications device(s) and the network, while mitigating potential interference. FIG. 1 is a block diagram schematically illustrating principle elements of an exemplary repeater in which the IGC of the present invention may be deployed.

[0034] As shown in FIG. 1, the repeater 2 is functionally positioned between a base station 4 of the wireless communications network (not shown) and the subscriber's Wireless Communications Device (WCD) 6. The repeater 2 is an "on-frequency" repeater, in that uplink and downlink RF signals are conveyed through the repeater 2 without altering the respective channel frequencies. The repeater 2 selectively receives and controls (i.e., amplifies and/or attenuates) RF signals, without performing any signal formatting or protocol conversion, thereby rendering the repeater 2 transparent to both the base station 4 and the WCD 6. The subscriber's WCD 6 may take the form of any conventional wireless communications device, such as, for example, Personal Digital Assistants (PDA's), wireless telephone handsets, pagers, and one and two-way wireless messaging devices.

[0035] It will be appreciated that the subscriber may possess multiple WCDs 6, and may use any one or more WCDs 6 simultaneously. Similarly, multiple subscribers may be located within the wireless space of a single repeater 2. However, for ease of description of the invention, the illustrated embodiment includes a single WCD 6 within the wireless space defined by the repeater 2.

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**[0038]** The Subscriber Coverage Unit (SCU) 10 operates to maintain a local wireless link 22 between the repeater 2 and the subscriber's WCD 6, and define the wireless space (not shown) encompassing the WCD 6. It is anticipated that the coverage area of the wireless space will be very much smaller than a conventional cell of the wireless communications network. For example, in some embodiments, it is expected that the wireless space will extend 25m (or less) from the SCU 10. Other embodiments may provide a larger or smaller coverage area, as desired.

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**[0042]** As shown in FIG. 2, the IGC 30 includes a wide-band uplink signal path 36 and a wide-band downlink signal path 38 coupled between the diplexers 32 and 34, and an IF down-converter and narrow-band detector 40, all of which

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[0045] More particularly, the IGC 30 of the present invention operates to control uplink channel RF signals received from the WCD 6 with a widely varying received power (e.g., between 0 and -60 dBm) for transmission to the base station 4 with a substantially constant repeater uplink Effective Radiation Power (ERP). In this respect,

the repeater uplink ERP can also be adjusted (by operation of the IGC 30) to a minimum value consistent with satisfactory link performance and prevention of system oscillation. However, following set-up of the network wireless link 14, it is anticipated that little, if any, adjustment in the repeater uplink ERP will be required, at least within the duration of a communications session. It is expected that a repeater uplink ERP of between about -23dBm and about +37dBm (depending principally on the distance between the repeater 2 and the base station 4) will yield satisfactory performance for most installations.

**[0046]** In the downlink path, the IGC 30 controls the downlink channel RF signals received from the base station 4 with a substantially constant received power for transmission to the WCD 6 with a varying repeater downlink ERP. The power of downlink RF signals received from the base station 4, will normally be determined during set-up of the network wireless link 14, and thereafter will not change significantly, at least within the duration of a communications session. It is anticipated that downlink RF signals received from the base station 4 will normally have a power of between about -120 and -60dBm, depending largely on the ERP of the base station 4 and the distance between the base station 4 and the repeater 2. The repeater downlink ERP will be continuously adjusted (by the IGC 30) to a minimum value consistent with satisfactory performance of the local link 22, and so implement adaptive coverage breathing (ACB), as will be described in greater detail below. It is anticipated that an repeater downlink ERP of up to about -20dBm will yield satisfactory performance for most installations.

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**[0049]** The VGA 46 preferably has approximately 60 dB of gain variation, and is cascaded with the fixed gain amplifiers 48 to enhance system linearity. The BPFs 50 following the VGA 46 limit the VGA noise to the uplink



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**[0051]** The feedback path 56 provides a 25 MHz bandwidth path which operates to ensure system stability by providing substantially instantaneous RF AGC feedback. The feedback path 56 closes the uplink AGC loop, which in turn limits system oscillation by automatically adjusting gain of the VGA 46 in the event of inadequate isolation between the DDA 16 and the SCA 24. The feedback path 56 also provides a means by which the gain of the uplink AGC 44 and the downlink slaved VGA 68 can be forced to a low level by the micro controller 42 to maintain stability during system setup, thereby ensuring the detection of weak desired signals in the downlink path 38 without the need for initial system isolation maximization and/or to disable the system in the event a major fault occurs.

**[0052]** The uplink slaved VGA 46 preferably has approximately 60dB of gain variation, and accepts a gain

**[0055]** The downlink AGC 66 preferably provides substantially constant output leveling over a wide input range. As shown in FIG. 4, the downlink AGC 66 is preferably provided as an extremely fast, wide dynamic range, highly linear block comprising a single VGA stage 70, a fixed gain amplifier 72 cascaded with a pair of band-pass filters 74a and 74b, and a directional

coupler 76. Inter-stage attenuators 78a-78c may also be included to optimize performance.

[0056] The downlink AGC VGA 70 preferably has approximately 60 dB of gain variation, and is cascaded with the fixed gain amplifier 72 to enhance system linearity while minimizing the cascaded noise figure. The BPFs 74a and 74b operate to limit VGA noise to the 25 MHz downlink bandwidth, thereby preventing out-of-band signals from capturing the downlink AGC 66 and saturating the downlink path output amplifier 90.

[0057] The directional coupler 76, which may be a 17 dB directional coupler, samples the downlink RF signal downstream of the VGA 70. The sample signal is supplied to a feedback path 80 which includes a cascaded RF amplifier 82 and log amplifier 84, and a feedback directional coupler 86 which samples the RF signal within the feedback path 80 and supplies the sample signal to the down-converter 40. The RF log amplifier 84 is preferably a variable detection log amplifier controlled by the micro controller 42. The output of the RF log amplifier 84 supplies a gain control signal to the downlink AGC VGA 70 and the uplink path slaved VGA 46, and may also be supplied to the micro controller 42. The feedback path 80 preferably provides a 25 MHz bandwidth path which operates to ensure system stability by providing substantially instantaneous RF AGC feedback. The feedback path 80 closes the AGC loop, which in turn limits system oscillation by automatically adjusting gain of the VGA 70 in the event of inadequate isolation between the DDA 16 and SCA 24. The feedback path 80 also provides a means by which the gain of the downlink AGC 66 can be forced to a low level by the

FOR DISCLOSURE

[0058] The downlink slaved VGA 68 preferably has about 60dB of gain variation, and accepts a gain control input from the uplink path AGC 44 to provide a hardware means to adaptively minimize the downlink output power. Thus, for example, the downlink slaved VGA 68 operates to reduce gain in the downlink path 38, as the received power of uplink RF signals increases, thereby reducing the coverage area of the subscriber's personal wireless space. It can be appreciated that in other embodiments of the preferred invention the slaved VGA 68 may be controlled directly by the micro controller 42 to accomplish the same task.

**[0060]** As shown in FIG. 5, the down-converter 40 comprises a switching input 96, an active mixer 98, a selectable band pass filter 100, a log amp detector 102, and a synthesizer 104 which can be selectively tuned by the micro

controller 42. The switching input 96 is controlled by the micro controller 42 to supply an RF signal from a selected one of the uplink and downlink AGCs 44 and 66 to the active mixer 98. Similarly, the synthesizer 104 is controlled by the micro controller 42 to supply an RF synthesized signal to the mixer 98. The RF sample signal and the synthesizer signal are processed by the mixer 98, in a conventional manner, to generate an intermediate frequency (IF) signal. This IF signal is used by the selectable BPF 100 to channel the RF sample signal by selectively attenuating portions of the RF sample signal lying outside a narrow pass-band (of, for example, about 30 KHz bandwidth) centered on the IF. The output of the selectable BPF 100 is supplied to the detection log amplifier 102, which operates to detect the presence (and power level) of desired RF signals in each of the uplink and downlink channels (depending on the state of the switching input 96). The output of the detection log amplifier 102 is supplied to the micro controller 42, and is used for decision making in accordance with the adaptive control algorithm (ACA).

[0061] Thus, when the switching input 96 supplies an RF signal from the uplink AGC 44 to the mixer 98, the selectable BPF 100 and detection log amplifier 102 operate to detect the power level and number of desired RF signals within the uplink channel 36, and this information can be used by the micro controller 42 to determine the signal format, set the appropriate power (i.e., gain) in the uplink path 36 and, for each detected desired RF signal, tune the synthesizer 104 to the corresponding downlink channel frequency (e.g., 45 MHz above the frequency of the detected signal), if necessary.

**[0063]** The design of the down-converter 40 enables the micro controller 42 to detect any number of weak desired uplink and downlink RF signals that are below either high-level wanted signals and/or adjacent carrier signals, or the system noise floor within a respective 25 MHz bandwidth. The micro controller 42 can provide a digital correction to each of the AGCs 44 and 66, thereby offsetting the respective leveled outputs to the weak desired signals. This arrangement enables the IGC 30 (and thus the repeater 2) to mediate signal traffic between the base station 4 and any number of WCDs 6 within the wireless space of the repeater 2.

[0064] The micro controller 42 comprises a micro-processor 106 operating under the control of suitable software that implements an Adaptive Control Algorithm (ACA), one or more Digital-to-Analog converters (DACs) 108 and Analog-to-Digital Converters (ADCs) 110 which operate, in a manner well known in the art, to provide translation between digital and analog signal formats, and thereby enable interaction between the micro controller 42 and other elements of the IGC 30. As will be described in

greater detail below, the adaptive control algorithm provides the necessary processing control for IGC operation without intervention after installation. It may also control operation during system set-up, in order to simplify installation of the repeater 2.

[0065] As shown in FIG. 5, the micro controller 42 may also include a configuration switch 112 to enable the subscriber to control an operating configuration (or mode) of the micro controller 42. The configuration switch 112, which may be provided as a conventional DIP switch, may have one or more settings allowing the subscriber to select an operating configuration (or mode) of the micro controller 42. Exemplary settings of the configuration switch may include:

- a "set-up" setting which may be used during installation of the repeater 2. For example, the micro controller 42 may reduce AGC gain (and thus transmission power levels) to enable the subscriber to adjust the placement and positioning of the DDU 8 and SCU 10;
- a "run" setting which may be used during normal operation of the repeater 2;
- a carrier A/B band select setting which may be used by the subscriber to select a desired carrier. Carrier A/B bands may be selected together or individually; and
- one or more settings by which the subscriber can choose to define maximum and/or minimum coverage areas of the subscriber's personal wireless space, e.g., by causing the micro

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controller 42 to limit gain of the downlink  
AGC 66.

[0066] As mentioned previously, the micro-processor 106 operates under the control of suitable software that implements the Adaptive Control Algorithm (ACA). In general, the ACA provides knowledge-based control over the functionality of the IGC 30, thereby providing dramatically greater versatility than is possible with conventional (analog math-based) RF signal processing techniques. In general, the ACA enables the following functionality of the IGC 30:

- selective tuning and controlling of desired RF signals;
- adaptive mitigation of interference in the subscriber's personal wireless space; and
- unconditional system stability (thus prevention of system oscillation) with imperfect isolation between the DDA 16 and SCA 24.

Each of these areas of functionality are described in greater detail below.

## Selective Tuning

**[0067]** As described above, the uplink and downlink paths 36 and 38 are wide bandwidth RF signal paths capable of controlling RF signals across the entire 25MHz bandwidth of the uplink and downlink channels. In contrast, the down-converter 40 is designed to detect individual desired RF signals within the wide bandwidth paths 36 and 38. In particular, the down-converter 40 operates to detect the presence (and power level) of an RF signal within a narrow



pass-band (of, for example, about 30 KHz bandwidth) centered on the IF frequency generated by the mixing of the synthesizer signal and the RF signal. By tuning the synthesizer 104 to various frequencies in succession, the micro controller 42 can scan the entire 25 MHz bandwidth of each channel to detect weak desired RF signals. The speed at which the micro-controller 42 can scan an entire channel (e.g. 25MHz band-width) will vary with the bandwidth of the selectable BPF 100. A larger bandwidth of the selectable BPF 100 increases the scanning speed, and thus allows the micro-controller 42 to isolate the discrete RF signals faster. In most cases, this increased processing speed is obtained at a cost of reduced sensitivity to weak signals. However, by dynamically switching the selectable filter 100 from a wide to narrow bandwidth and thereby restricting the detection to a narrowband centered on the intermediate frequency (e.g. by reducing the bandwidth of the selectable BPF 100), the down-converter 40 and micro controller 42 can detect weak desired RF signals that are embedded in noise.

[0068] More particularly, the down-converter 40 and micro controller 42 cooperate to implement a digital offset correction technique in which the gain of a wide-band AGC is set for RF signals that may not have captured the AGCs. As is known in the art, a wide-band AGC will normally level to the highest signal that captures the AGC within a defined bandwidth. If no signals are present, the AGC may level to the thermal and system noise of a given bandwidth. If weak desired (i.e., uplink or downlink RF) signals are present, and the AGC bandwidth is much larger than the signal bandwidth (such that noise masks the weak signals) a conventional AGC will tend to be captured by the noise rather than the weak desired signal. In the present invention, the narrow-band detection capability of the

[0069] In addition, the ACA can implement a variety of signal evaluation techniques, as desired. For example, by controlling the bandwidth of the selectable BPF 100 and monitoring the detection signal output by the detector 102, the micro controller 42 can detect changes in the RF signals in each of the paths 36 and 38. These changes can be used to identify the format of the RF signals being used by the subscriber's WCD 6. In particular, periodic pulse-like changes in the signal level in the uplink path 37 (independent of selectable BPF 100 bandwidth) indicates that the WCD 6 is using a narrow-band pulsed (e.g., Time Division Multiple Access (TDMA)) signal format. Changes in power level due to changes in the bandwidth of the selectable BPF 100 indicates that the WCD 6 is using a broad-band (e.g., Code Division Multiple Access (CDMA)) signal format. If neither of these types of changes are detected, then the WCD 6 is using a narrowband continuous (e.g., Advanced Mobile Phone Service (AMPS)) signal format. Once the signal format is known, the ACA can select appropriate parameters for optimizing the gain of uplink and downlink paths 36 and 38.

[0070] As is known in the art, as the number of subscribers and WCDs increases, the problem of interference

becomes progressively more acute. The type and degree of interference varies from one network to the other, and may vary from area-to-area within a network. So-called "Smart" antenna technology has been used in a wide variety of applications to combat interference. This smart antenna technology can be effectively applied at the base station 4 to reduce the interference problem for both the downlink (interference to the WCD 6 from other base stations) and the uplink (interference to the base station 4 from other WCDs) communication paths. However, smart antenna technology has generally not been used to mitigate interference occurring at the WCD end of the link. This is largely due to the size and power constraints of the WCD, and the requirement that the WCD's antenna must be omni-directional to successfully connect to, and communicate with, the base station 4.

[0071] In accordance with the present invention, the repeater 2 implements a technique of Adaptive Interference Mitigation, in which RF interference in the subscriber's personal wireless space is mitigated by a combination of one or more of: physical antenna separation; the use of a narrow beam network link 14 between the repeater 2 and the base station 4; and Adaptive Coverage Breathing (ACB). Physical separation of the DDA 16 and SCA 24 reduces the possibility that the WCD 6 will receive uplink RF signals transmitted by the DDA 16 toward the base station 4, and hence all but eliminates the possibility of the WCD receiver being overwhelmed by the DDA's ERP. Further isolation between the DDA 16 and the WCD 6 is achieved by the use of a directional antenna for the DDA 16, which results in a comparatively narrow beam propagation path of the network link 14. As will be appreciated, the probability that the WCD 6 will pass into

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the narrow propagation path of the network link 14 can be reduced (to near zero) by suitable placement of the DDA 16.

[0072] Similarly, interference within the subscriber's wireless space due to signals propagating from other base stations is dramatically reduced, because the DDA 16 will tend to only receive signals transmitted by base stations lying within the narrow propagation path of the network link 14. As a result, signals emitted by base stations lying outside the network link 14 will not be amplified by the DDA 16 and transmitted into the subscriber's personal wireless space by the repeater 2. Unlike conventional mitigation schemes, where the interference is reduced relative to the desired signal (or itself), the repeater 2 operates to selectively detect and amplify the desired signal(s) relative to the interference.

[0073] With this discrimination in hand, the IGC 30 amplifies and conditions the desired RF signals for transmission into the subscriber's personal wireless space such that the WCD 6 receives a substantially constant downlink signal power, independent of its location relative to the repeater 2. Thus the ACA implements a technique of Adaptive Coverage Breathing (ACB), such that the coverage area of the subscriber's personal wireless space is automatically adjusted in order to ensure: acceptable signal-to-noise ratio in both the uplink and downlink paths of the local link 22; the received downlink signal power is maintained substantially constant at the WCD 6; and transmission (i.e., uplink RF signal) power from the WCD 6 is minimized.

[0074] In general, Adaptive Coverage Breathing (ACB) comprises a technique of RF power management that enables

[illegible]

[0075] In operation, a minimum acceptable uplink channel RF signal power of the WCD 6 can be negotiated with the base station at a start of a communications session. This uplink channel RF signal power is then maintained substantially constant by the WCD 6 (during the communications session). The IGC 30 adapts to changes in the position of the WCD 6 by accepting widely varying uplink channel RF signal powers from the WCD 6 and controlling the downlink channel ERP to hold the downlink RF signal power received by the WCD 6 substantially

[illegible]

## Unconditional System Stability

[0077] As is known in the art, on-frequency repeaters can oscillate if the system gain exceeds the total system isolation (e.g., the front to back ratios of the DDA 16 and SCA 24; polarization loss; and propagation path loss). For this reason, and depending on the required link performance, installation of on-frequency repeaters can be very difficult. In accordance with the present invention, the IGC 30 implements Adaptive Coverage Breathing (ACB) and

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	

[0079] One difficulty in ensuring system stability is that leakage signals (i.e., signals propagating between the DDA 16 and SCA 24) are correlated with desired signals received from the base station 4 and WCD 6. In particular, since downlink RF signals are transmitted by both the base station 4 and the SCA 24 at the same frequency, imperfect isolation between the SCA 24 and the DDA 16 will result in the DDA 16 receiving signals from both the base station 4 and the SCA 24. Since these signals will be closely correlated (in time) it is difficult to determine what portion of the total signal received at the DDA 16 is the desired downlink RF signal from the base station 4, and what portion is the undesired leakage signal from the SCA 24. Similarly, imperfect isolation between the SCA 24 and the DDA 16 will result in the SCA 24 receiving uplink RF signals from both the WCD 6 and the DDA 16. Since these signals will be closely correlated, it is difficult to determine what portion of the total signal received at the SCA 24 is the desired uplink RF signal from the WCD 6, and what portion is the undesired leakage signal from the DDA 16.

[illegible][illegible]

[0082] The unique code may be provided as any signal pattern that can be reliably detected within the uplink and downlink RF signal traffic. Preferably, the unique code is transmitted as a form of RF modulation (either in amplitude and/or phase changes that instantaneously affect the entire system operating RF bandwidth), as this provides for a more accurate estimate of the degree of signal leakage at any frequency of interest. In this case, however, it is important that the unique code be selected such that it can be inserted into the uplink and downlink paths 36 and 38 without disrupting the RF signal traffic or disturbing the performance of the base station 4 and WCD 6. Thus in preferred embodiments, the unique code is provided as a low level dither (or fade) imposed on the entire RF signal traffic within each path 36 and 38.



2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808 2809 2810 2811 2812 2813 2814 2815 2816 2817 2

[0085] Similarly, the micro controller 42 can control the uplink slaved VGA 46 to dither the uplink path gain, and thereby impose an "amplitude modulation" onto the uplink RF signals. Here again, the modulation power can be kept low enough to avoid disrupting the base station 4, and the variations in signal power will have no effect on the frequency modulated content of the uplink RF signals. Simultaneously, the micro controller 42 can monitor the detection signal generated by the uplink AGC 44 to detect

[illegible]

[0087] The predetermined threshold level of acceptable signal leakage can be suitably selected to provide a balance between system stability (i.e., resistance to oscillation) and performance of the network and local wireless links 14 and 22. When taken in combination with other sources of isolation between the SCA 24 and the DDA 16 (e.g., front to back ratios of the DDA 16 and SCA 24; polarization loss and propagation losses), it is possible to set a threshold level which ensures

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808 2809 2810 2811 2812 2813 2814 2815 2816 2817 2818

**[0089]** The embodiment(s) of the invention described above is(are) intended to be exemplary only. The scope of the invention is therefore intended to be limited solely by the scope of the appended claims.